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E MISSILE AND ITS PERFORMANCE - AN ANALYSIS

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ABSTRACT

This study mainly deals with the design and structural analysis of missile motor body. This is to design three missile motor bodies with different dimensions and analyze them by applying three different materials for the corresponding loads, which act when two types of propellants are used and find the material with less deformation and better load bearing capability. The main aim of this study is structural analysis performed on the antitank guided missile MILAN 2T motor body, which was designed in NX for varying dimensions and thickness of three motor body designs and analyzed in the NX simulation by applying the loads imposed by two different propellants, namely double base and triple base propellants.

KEYWORDS: Antitank Guided Missile, Milan-2T, Classification of Missiles, Propellant Design, Designing of Missile Motor Body & NX Application

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Original Article

INTRODUCTION

A missile is a self-guided weapon system. The missile mainly is divided into three sections, such as the warhead section, motor body, and nozzle. Missiles have four system components in it, they are target/guidance system, flight system, warhead, engine system. MILAN 2T is an anti-tank guided missile, which is considered as a reference missile for the work carried out in this project. It is a short-range missile. Anti-tank guided missiles could be launched from tanks, aircraft and also from shoulder mounted launcher. The section motor body consists of propellant and igniter (fuse). The Milan 2T uses solid propellant for its operations.

Figure 1: Milan 2T Missile

In the Soviet Union and the United States, the sniper tank concept took the form of tanks armed with antitank guided missiles. In the case of the Soviet Union, several missile tanks were under development during the late 1950s.

These benefited from the heavy-handed patronage of Nikita Khrushchev, who had come to believe that gun-armed tanks would be rendered obsolete by anti-tank guided missiles. None of these projects, however, survived Khrushchev's fall from power, where the Soviet tanks were turretless, the two American tanks to be armed primarily with missiles had conventional turrets. The first of these was a Sheridan a light tank officially classified as an armored reconnaissance vehicle. The other was the M60A2, a modified version of the standard Patton tank. Both of these vehicles carried a short 152mm gun that could fire either unguided high explosive rounds or shillelagh antitank guided missiles.

The inherent deficiency of both turrets less gun-armed tanks and tanks armed with antitank guided missiles was that they were just too specialized. They were optimized for the task of killing another tank but largely unable to do all the other things those tanks have traditionally done on the battlefield.

Tanks armed with antitank guided missiles are even more specialized than turret less gun tanks, where the latter can fire high explosive rounds, smoke rounds and other ordnance, the missile tank can only fire missiles with specialized antitank warheads. Indeed, as the latter were more thoroughly optimized for the task of penetrating tank armor, they become less useful for other battlefield purposes. In 1982, for example, British infantrymen fighting in the Falkland Islands used man-portable Milan antitank guided missiles to destroy Argentine machine gun positions.

One of the most important categories of a guided missile to emerge after world war-2 was the antitank missile. The first guided antitank missiles were controlled by electronic commands transmitted along extremely thin wires played out from a spool on the rear of the missile. Propelled by solid fuel sustainers, these missiles used aerodynamics fins for lift and control. Tracking was visual using a flare in the missile's tail and guidance commands were generated by a hand operated joystick. In operating these missiles, the gunner simply superimposed the tracking flare on the target and waited for impact.

MILAN-2T

- Basing: armored
- Management system: Office for radio
- Warhead: cumulative
- Range: 2 km
- Year development: 1974

Complex" Milan "was developed based on the requirements of the armed forces of Germany and France, and with the general requirements of the NATO commands to weapons. As a result of the inter-ethnic association, the "Euro missile" system has been developed, thanks to the high-performance characteristics of the most widely-spread (after ATGM "TOW") of all used in different countries, anti-tank missiles. LAW "Milan" is an armed land force of 40 countries, including Germany, France, and other NATO countries.

Modernization program LAW "Milan", entered service in 1974, had the following basic requirements,

- Increase the effectiveness of warhead missiles on new types of armor.
- Increase immunity guidance system.

Ensuring compatibility with an advanced rocket launcher and thermal sight without modifications; and preservation of the former range of action.

As a result, the samples improved rockets, the designation "Milan-2." Series production of these missiles launched in 1984 and 1985 began to supply to their armed forces of Germany and France.

The effectiveness of the K-115 warhead significantly improved by increasing the diameter from 103 to 115 mm, the use of more powerful explosives (otolith) and increasing its weight from 1.2 to 1.8 kg, increasing the distance from the obstacle warhead detonation from 2 to 2.5 calibres by setting nasal tip of the rocket, which also provides a reliable undermining warhead meeting at angles up to 80° from normal. The explosive charge has a conical recess with a cumulative angle of 50°, lined with a copper sheath thickness of 1.9 mm. Warhead K-115 missiles" Milan-2 "with an explosive charge and a mass greater power than the previous warhead.

Penetration HEAT warhead depends strongly on the distance from the detonation of the explosive charge barrier. At undermining the new charge warhead using the tip length is 280mm; 800mm armor is over (homogeneous armor). When blowing in the laboratory at a distance of about 10 calibers it was more than 1000 mm, but practically to achieve this efficiency is only possible with the help of proximity fuse.

When punching homogeneous frontal armor of modern tanks new warhead missiles "Milan-2" retains residual armor up to 200 mm required for zabronevogo action. The practical application of missiles "Milan-2" showed that they have more destructive power due to the unburned fuel sustainers engine. Fuel burn for 12c at 1125 - 1200°C, and in contact with missiles within this time in goals such as ships or strengthening, it becomes a major damaging factor. Furthermore, although the limited maneuverability missiles (angular velocity changes the direction of flight is not more than 20mrad/s), it can be used to defeat helicopters on a collision course or are hovering. In this case, the rocket can rise to a maximum height of 380 m at a distance of 1800 m.

Sights complexes "Milan" Northeast France supplied with a cooling device, powered by a compressed gas cylinder. The Weight of cylinder is 700g, the gas pressure in the cylinder 329 atm. At a temperature of 15°C, it is cooled to 77°C.

Northeast Germany opted for a sight cooling device developed by AEG (Germany) instead of the gas cylinder. Battery power and a cylinder of compressed gas (capacity 0.33L or 0.66) ensure continuous operation of sight for 2 hours, after which can be quickly replaced. It is easy to maintain and operate, designed for working conditions in the temperature range from -40 to +52°C. The reliability of its reliability matches the remaining elements of the complex. Target detection is provided at a range of 4000 m, target identification 2, 3x2, 3m (dimensions of the tank in the front), and start pointing missiles - at a distance of 2000 mA person can be detected at a distance of up to 600m Field of view 3°x6°; spatial resolution of 0.175m/rad minimum detectable temperature difference of 0, 16°C; readiness time operation after turning 30. DC supply voltage (7.2 +0.1) V. Weight sight with battery power and about 9kg gas cylinder.

To Improve Noise Immunity

Complex guidance system, an additional communication channel. The missile is equipped with an advanced gyro light emitting diode and a new electronic control unit, which allowed her to improve the process guidance.

The advantages are

- The possibility of using various infantry divisions.
- Rapid deployment to any firing position and after 10-12 seconds after that the possibility of launching missiles.
- Application from the ground or installed to light machines without modification.

Along with the advantages of complex notes some shortcomings that emerged in the process of testing, in combat conditions and the emergence of new types of armor.

These include,

- Relatively large weight for portable complex.
- Strong enough to emit smoke sustainers rocket engine, which leads to the closure of the field of sight at 1.5-3 seconds after start-up, depending on weather conditions.
- The possibility of losing in a missile tracking device, receiving her radiation tracer, amid intense radiation in the real battlefield (e.g., against the burning cars).

The action of reactive armor missile "Milan-2", as well as other existing anti-tank, has proved ineffective.

Because of these shortcomings and to extend the life cycle of complex "Milan" the ways of its further improvement. Primarily seeks to ensure the necessary efficiency missiles at the action on reactive armor.

Firm MBB (Germany) conducted to develop a new warhead for missiles "Milan", containing two cumulative explosive charges. First, an auxiliary charge of about 30 mm in diameter located in the tip of the telescopic warhead at a distance of 450 mm from the second main charge placed in the body for the first warhead. Auxiliary charge undermines impact tip of the barrier by 0.5 m/sec before the main, intended to destroy the layer of reactive armor, the second charge - to pierce the main armor. The missile with a new warhead was designated "Milan-2T" (tandem warhead) or "Milan-3".

MBB firm has also developed a new multi-purpose warhead to defeat light armored vehicles, manpower, and equipment. This contains shaped charge warhead explosives, armor penetration of up to 350 mm, and about 1,000 steel balls with a diameter of 4 mm, stacked around the explosive charge.

Other Possible Improvements to the Complex "Milan" Include

- Increase the range of the missiles to 4,000 m (with an increase in the mass of the rocket to 9.5 kg).
- Equipping existing warhead missiles noncontact (laser or pulsed Doppler) fuse, which will increase the 103-mm armor-piercing warhead and to 25-30%.
- Development of a new warhead weighing 3kg for punching and combination of reactive armor.
- Equipping missiles within tracer modulated radiation or laser diode with the encoded radiation to improve noise immunity tracking device.
- Replacement of analogy servo and decoding digital devices that will produce sophisticated encoding of infrared tracer and program tracking device to accept only such radiation. Due to this increase the reliability and robustness of the guidance system, the sensitivity of the rocket to controls.
- Installing smokeless rocket motor that will reduce the minimum range missile launch and telltale signs.

- Reduction in size and weight of the container carrying missiles (with four missiles his weight 82kg) more than 3kg.
- Reduction in size and weight of the thermal sight "Mira" by using electric instead of gas cooling method and other improvements.

The below table describes the performance parameters of the MILAN 2T missile. MILAN is a light, portable missile with a range of 75 to 2,000 meters.

Table 1: Performance of Milan 2T

Range of fire	25-2000m
Maximum speed, km / h	720
Flight Time missiles at a range of 2,000 m, with	12.5
Time of flight range missiles at 1000 m, with	7.3
Weight rocket kg	6.73
warhead weight, kg	3.0
explosive warhead Weight, kg	1.8
weight of the rocket from the launch tube, kg	12.0
PU Weight with tripod, kg	16.5
Weight sighting unit, kg	4.2
Rate start / min	3
temperature range of combat use, ° C	-40 to +52
Technical reliability,%	More than95
Penetration by the action on the homogeneous armor, mm	1000

The British swing fire and the French-designed, internationally marketed MILAN was similar in concept and capability to TOW (tube launched optically tracked wire guided)

Light forces currently use the MILAN anti-tank missile which was developed in the late 1970s and has become increasingly less effective due to advances in modern tank armor. MILAN is due to go out of service in 2007 with a javelin as a direct replacement.

It has been observed that different materials have been employed for the missile motor body. A better material in terms of strength to weight ratio which would possibly sustain the loads without compromising on the performance of the missile was the main criteria of this project.

The NX8 product development solution from Siemens PLM (product lifecycle management) Software delivers new capabilities and more powerful tools for design, simulation, and manufacturing. The latest release builds on Siemens' high-definition PLM technology framework to provide more visual information and analytics that improve collaboration and decision-making. Customer-driven enhancements for CAD modeling validation, drafting, simulation/CAE, tooling design and machining boost productivity throughout product development to help companies deliver higher quality products faster and at lower costs.

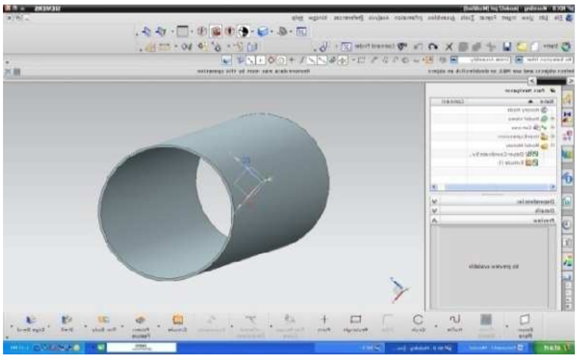


Figure 2: Design of Motor Body-1

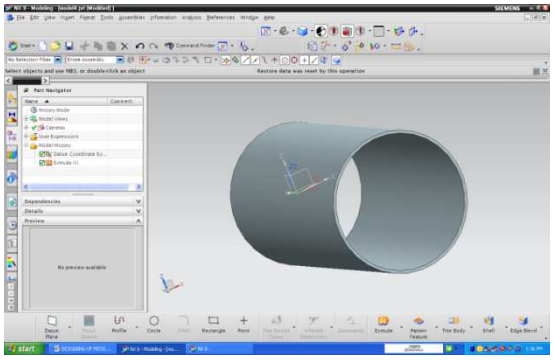


Figure 3: Design of Motor Body-2

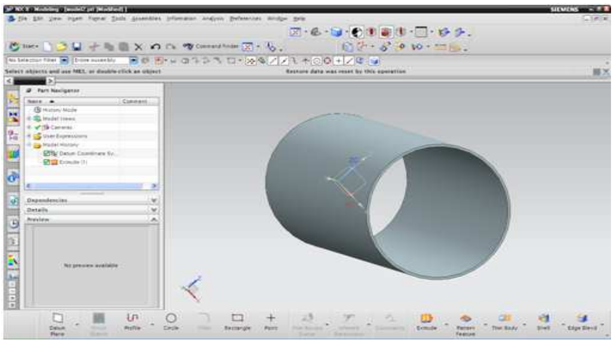


Figure 4: Design of Motor Body-3

Summary: The design parameters for the three types of motor body are mentioned with the images.

NX 8 for Simulation can drastically reduce the time you spend preparing and solving analysis models by up to 70 percent. Siemens has strengthened and expanded upon the technologies from its long simulation legacy and has brought them together to form NX Computational aided engineering, a modern and integrated high-end analysis environment, and NX Nastran, a premium finite element solver. NX 8 introduces over 200 new capabilities to both NX CAE and NX Nastran (simulation) that enable you to rapidly build, update and simulate analysis models, make smarter engineering decisions and deliver better products faster Finite element modelling and analysis solutions. The advanced simulation environment is a very powerful computational aided design embedded computational aided engineering tool. It gives an overview of how to set up a Finite Element Analysis. Synchronous modelling, Idealizing geometry, meshing, loads, constraints, adaptive meshes, optimized geometry, assemblies, and post-processing. The following is the procedure of the NX 8 simulation.

- Model creation-open file
- Start-advanced simulation.
- Simulation navigator-select and right click-new fem and simulation-ok-change the name-ok.
- Double click the fem model
    - 3D tetra mesh will open
    - New collector-create physical-material
    - Assign the material –ok
    - Deselect the automatic creation-select the body-ok.

- **Window:** -Simulation-Select-Constraint Type
- **Constraints:** -Fixed Constraints- Change View
    - fix the constraints on two sides
    - load type

    -Pressure-select the inner body and enter a value

    - Double base propellant (19.37N/mm2)
    - Triple base propellant (33.33N/mm2)
- Solve: -ok
- Results
    - Deformation
    - Maximum shear stress
    - Von Mises stress

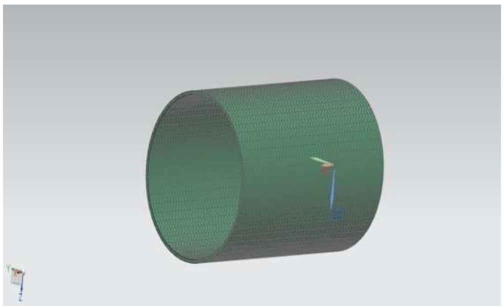


Figure 5: Meshing of Motor Body

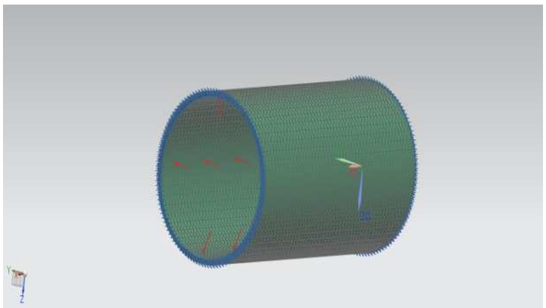
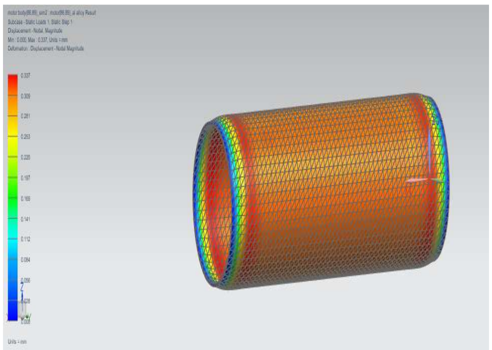


Figure 6: Motor Body with Loads

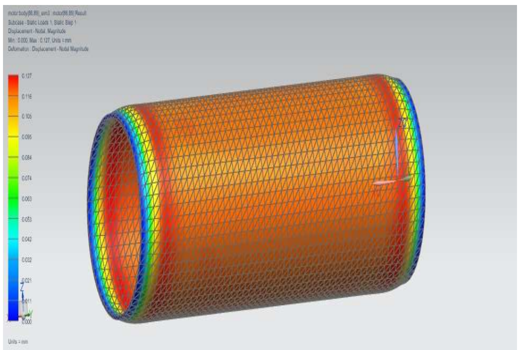
Summary: The design software NX8 is described and the steps underlying the process/sequence of operations for the complete design of the motor body are described following the sequence of operations for the structural analysis in the NX simulation.

RESULTS AND DISCUSSIONS

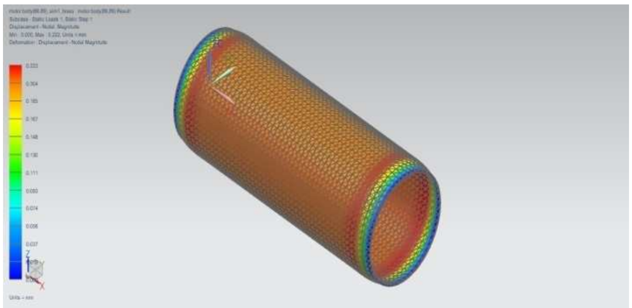
Results of All Motor Bodies by using Double Base Propellant



(a) Aluminium Alloy 606

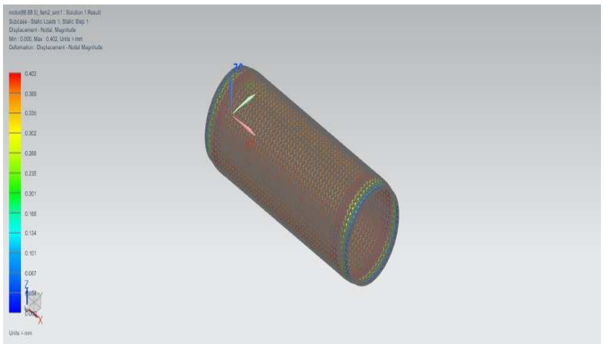


(b) Maraging Steel

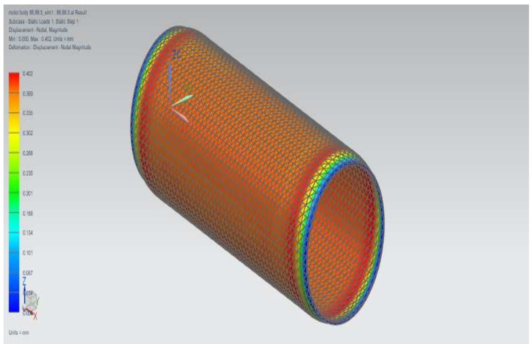


(c) Brass

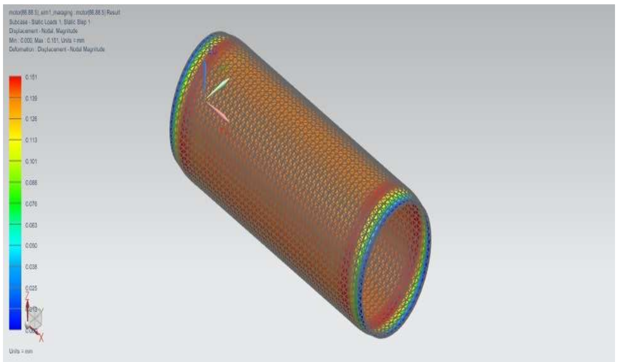
Figure 7: Deformation of Motor Body-1 with Three Materials



(a) Aluminum Alloy 6061

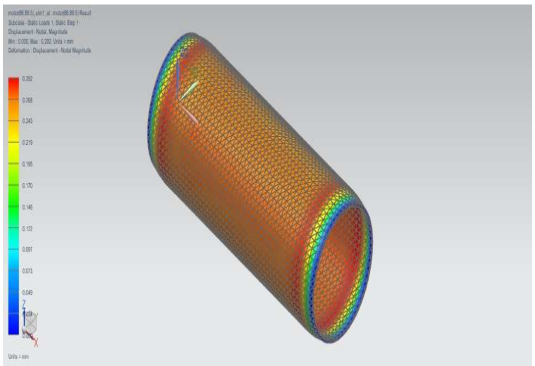


(b) Maraging Steel

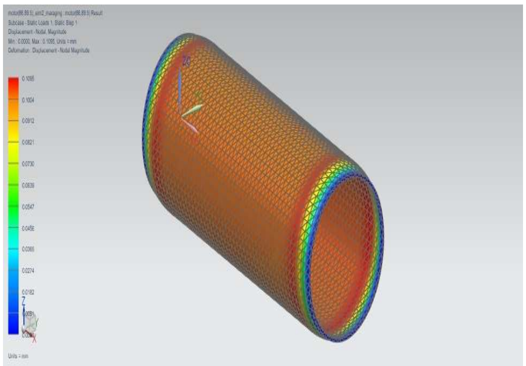


(c) Brass

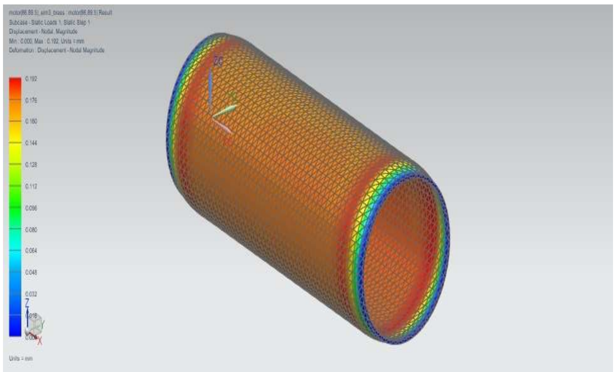
Figure 8: Deformation of Motor Body-2 with Three Materials



(a) Aluminium Alloy 6061



(b) Maraging Steel



(c) Brass

Figure 9: Deformation of Motor Body-3 with Three Materials.

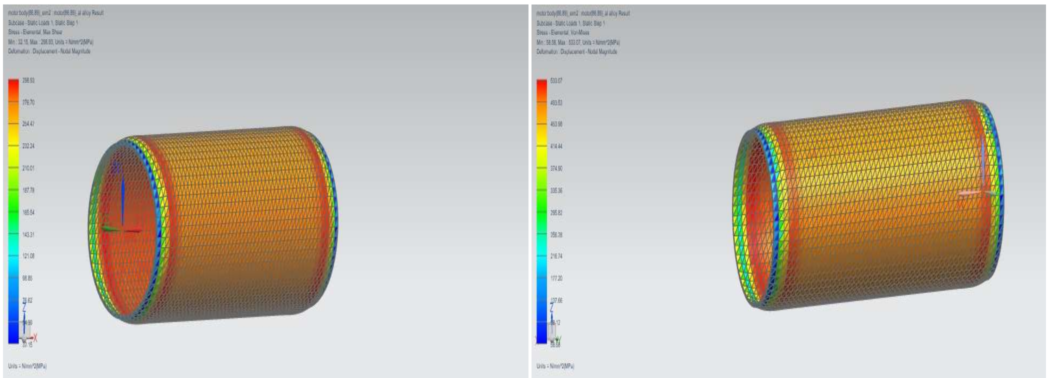


Figure 10: Shear Stress and Vonmises Stress for Aluminium Alloy 6061 Material of Motor Body-1

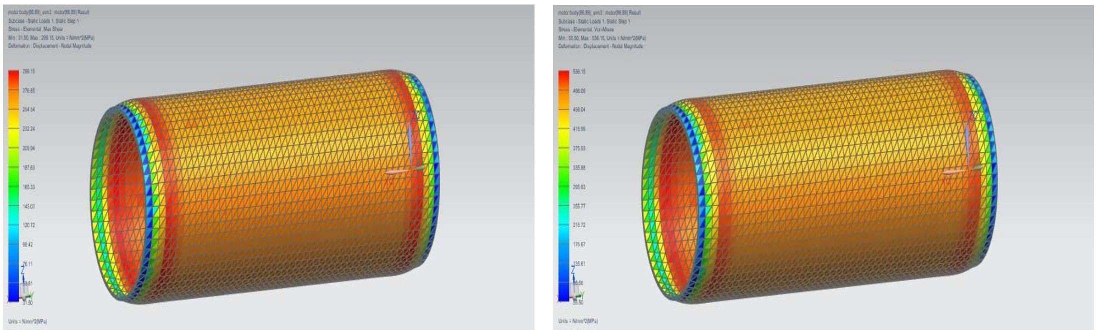


Figure 11: Shear Stress and Vonmises Stress for Maraging Steel Material of Motor Body-1

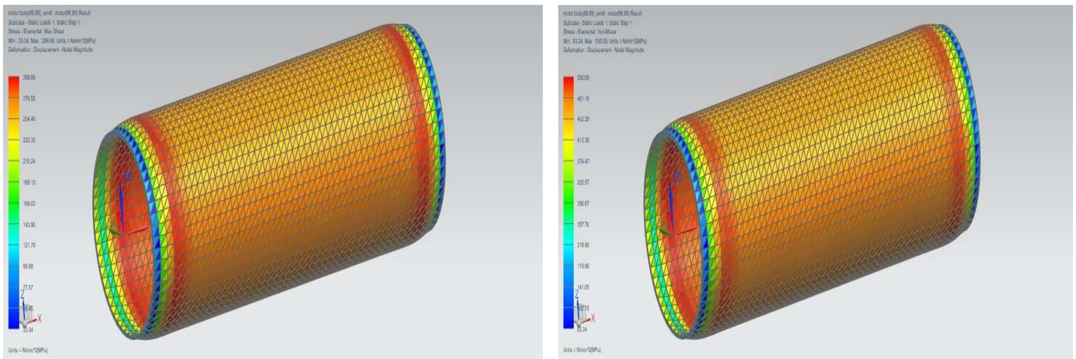


Figure 12: Shear Stress and Vonmises Stress for Brass Material of Motor Body-1

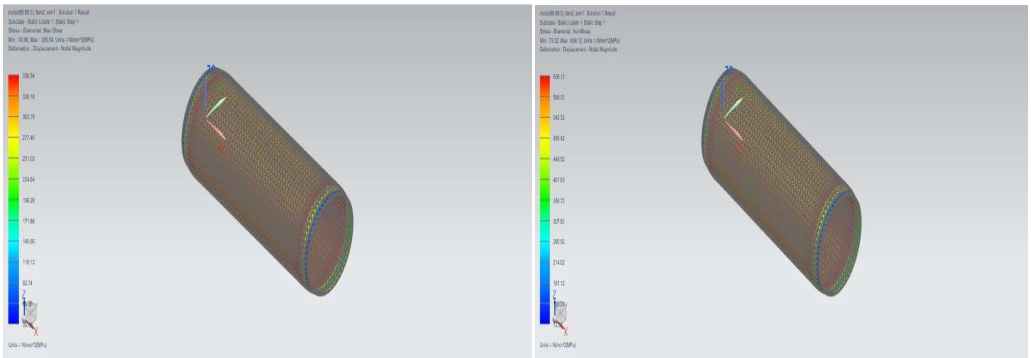


Figure 13: Shear Stress and Vonmises Stress for Aluminium Alloy 6061 Material of Motor Body-2

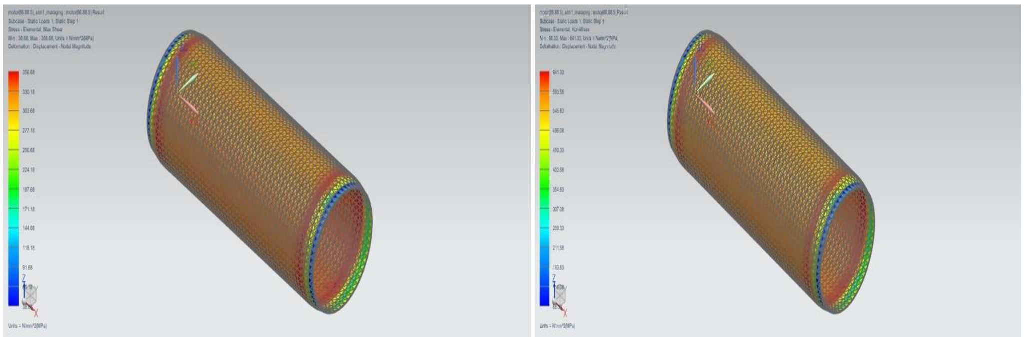


Figure 14: Shear Stress and Vonmises Stress for Maraging Steel Material of Motor Body-2

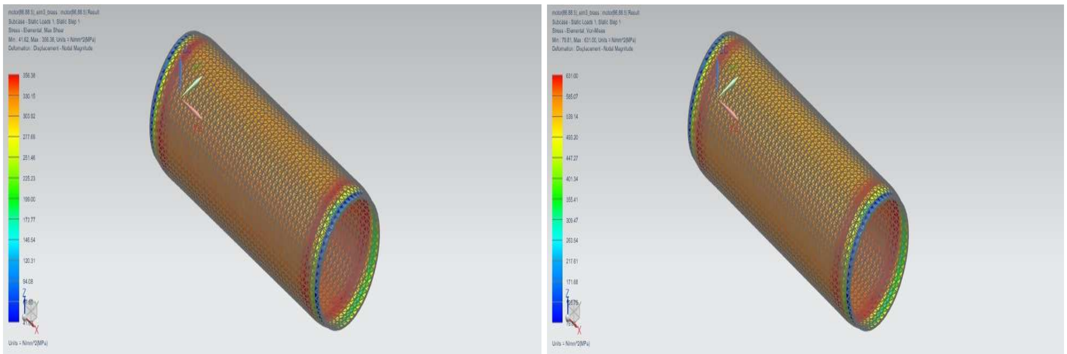


Figure 15: Shear Stress and Vonmises Stress for Brass Material of Motor Body-2

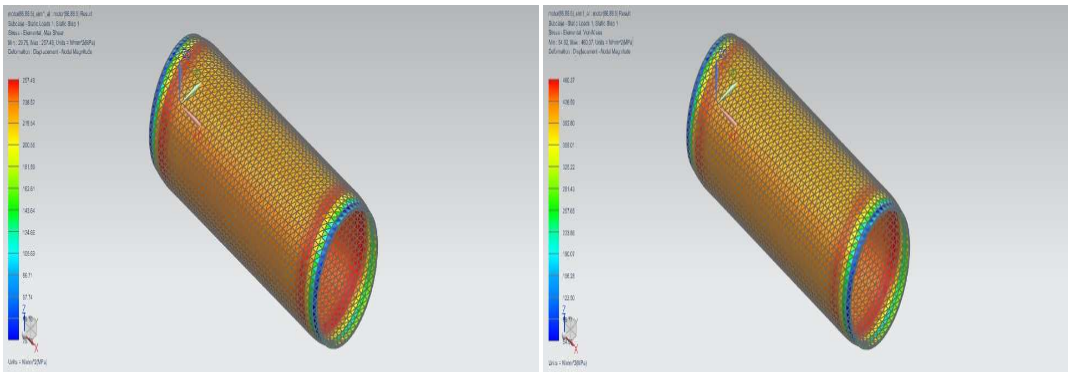


Figure 16: Shear Stress and Vonmises Stress for Aluminium Alloy 6061 Material of Motor Body-3

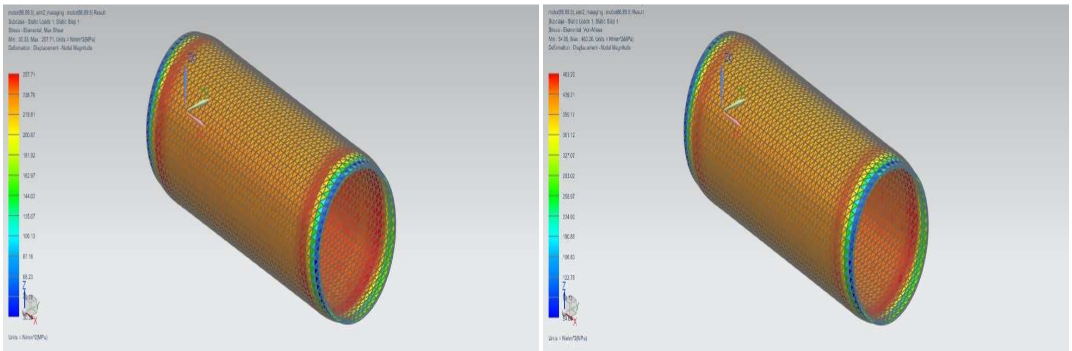


Figure 17: Shear Stress and Vonmises Stress for Maraging Steel Material of Motor Body-3

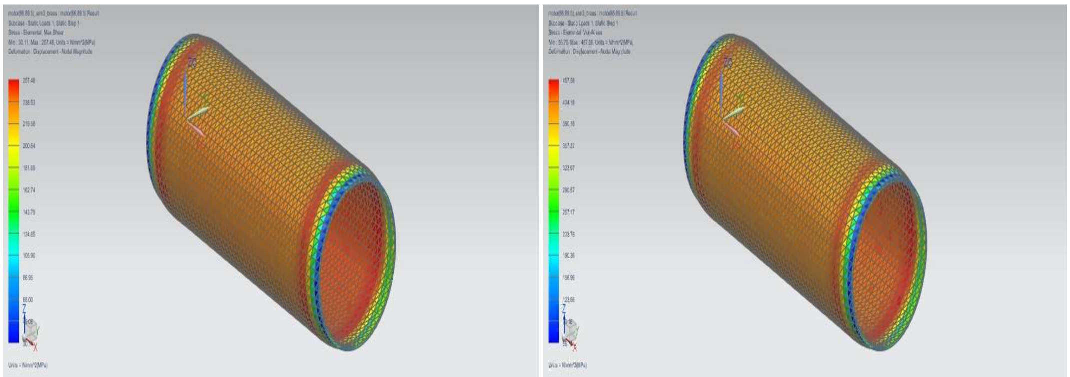


Figure 18: Shear Stress And Vonmises Stress For Brass Material Of Motor Body-3

Table 2: Results of Motor Body- 1

Material	Deformation		Shear Stress		Von Mises	
	Min	Max	Min	Max	Min	Max
Al alloy (6061)	0	0.337	32.15	298.93	58.58	533.07
Maraging steel	0	0.127	31.50	299.15	55.50	536.15
Brass	0	0.222	33.34	298.69	63.24	530.09

Table 3: Results of Motor Body- 2

Material	Deformation		Shear Stress		Von Mises	
	Min	Max	Min	Max	Min	Max
Al alloy (6061)	0	0.402	39.98	356.54	73.32	636.12
Maraging steel	0	0.151	38.68	356.68	68.33	641.33
Brass	0	0.265	41.62	356.38	79.81	631.00

Table 4: Results of Motor Body- 3

Material	Deformation		Shear Stress		Von Mises	
	Min	Max	Min	Max	Min	Max
Al alloy (6061)	0	0.292	29.79	257.49	54.92	460.37
Maraging steel	0	0.1096	30.33	257.71	54.69	463.26
Brass	0	0.192	30.11	257.48	56.75	457.58

Results of Motor Body-3 By Using Triple Base propellant

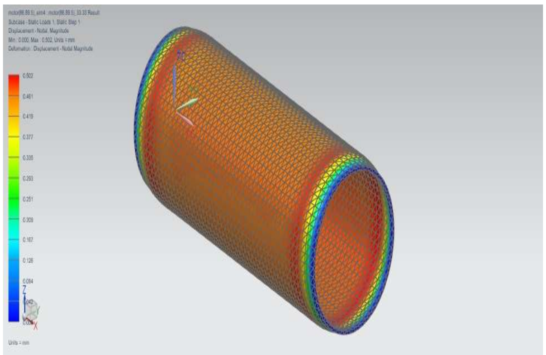
Geometric parameters of missile motor body

The diameter of the outer motor body: 89.5mm

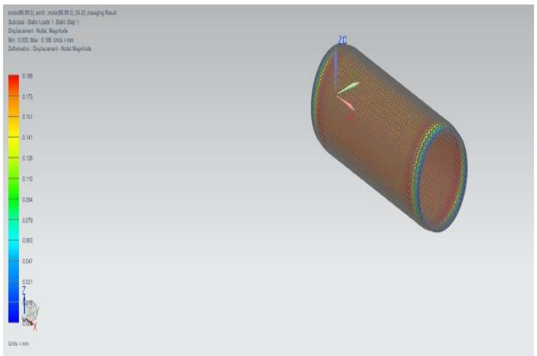
The diameter of the inner motor body: 86mm

Length of motor body: 244.7mm

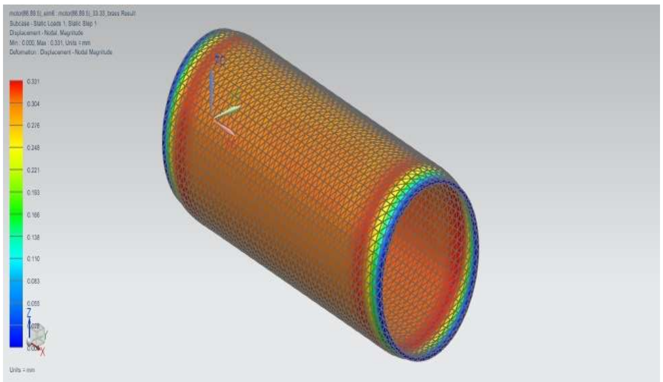
Pressure : 33.33N/mm2



(A) Aluminium Alloy 6061



(B) Maraging Steel



(c) Brass

Figure 19: Deformation of All the Materials

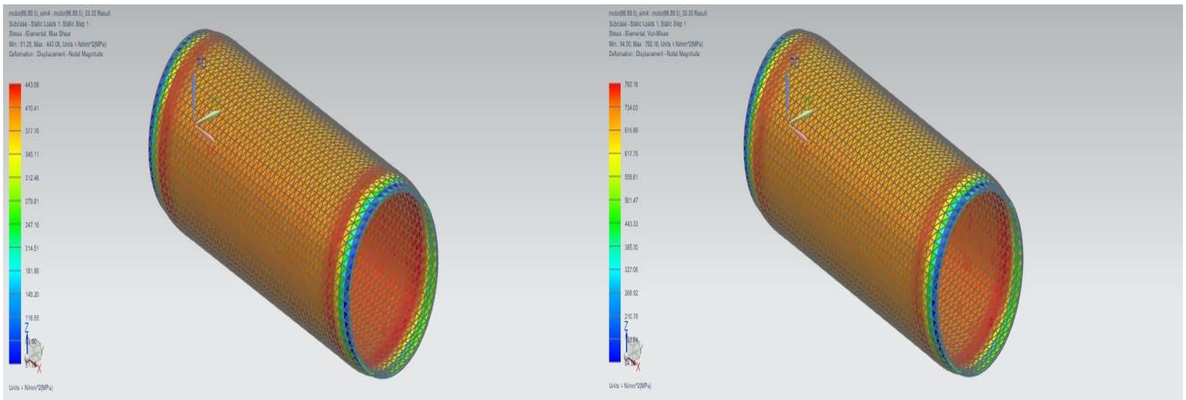


Figure 20: Shear Stress and Vonmises Stress of Aluminium Alloy 6061material

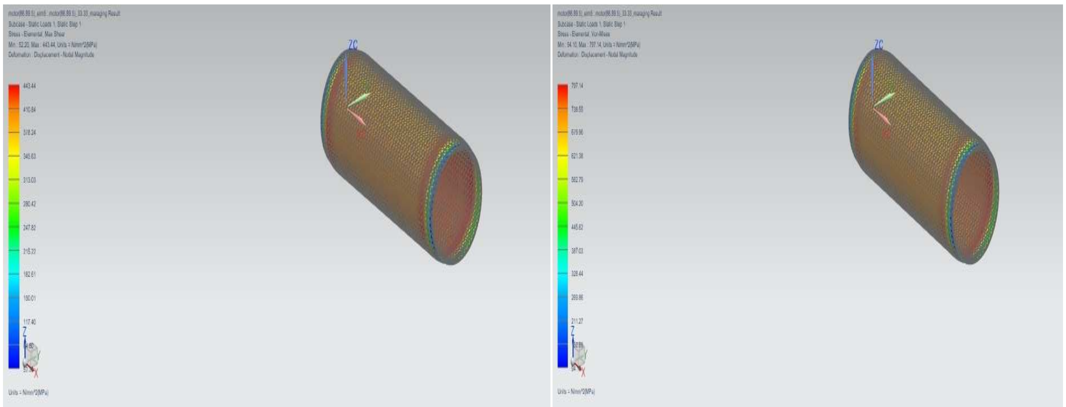


Figure 21: Shear Stress and Vonmises Stress of Maraging Steel Material

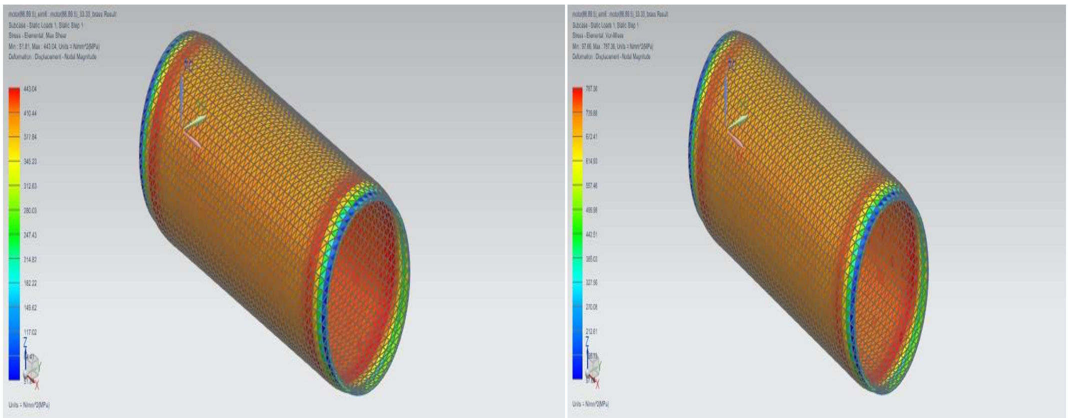


Figure 22: Shear Stress and Vonmises Stress of Brass Material

RESULTS

Table 5: Results of Motor Body -3 by Using Triple Base Propellant

Material	Deformation		Max Shear		Von Mises	
	Max	Min	Max	Min	Max	Min
Aluminum alloy 6061	0.502	0	443.06	51.25	792.16	94.50
Maraging steel	0.188	0	443.44	52.20	797.14	94.10
Brass	0.331	0	443.04	51.81	787.36	97.66

VALIDATION

Validation of Missile Performance

Simple formula for estimating missile performance:

$\Delta V = 10 \times Isp \times \ln$ (initial weight / final weight) ms-1

For Double Base Propellant

Initial weight of missile = 3.0 kg

Final weight of missile = 1.8kg

Specific impulse = 296 sec

$\Delta V = 10 \times Isp \times \ln$(initial weight / final weight)m/s

= 10 × 296× ln(3.0/1.8)m/s

ΔV = 1512.043 ms-1

For triple base propellant:

Initial weight of missile = 3.0kg

Final weight of missile = 1.8kg

Specific impulse = 391 sec

ΔV = 10 × Isp× ln (initial weight / final weight) ms-1

= 10 × 391× ln (3.0 /1.8) ms-1

ΔV = 1997.329 ms-1

A thin plate is a prismatic member having a small thickness, and it is the case for a typical lamina. If a plate is thin and there are no out-of-plane loads, it can be considered to be under plane stress. Let us consider that the radial and longitudinal stress acting on the motor body (which looks like a thin shell) be assumed as the plane stress carrying loads such that a small lamina on the surface of the motor body casing can be considered to be under loading and be analyzed theoretically. A thin, the lamina is assumed to be under a state of plane stress and the equations that govern the stress and strain are shown below where Qij is the reduced stiffness coefficients. For a lamina, these engineering elastic constants are E1, E2, υ12, and G12.

$$\begin{bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{bmatrix}=\begin{bmatrix}Q_{11} & Q_{12} & 0\\ Q_{12} & Q_{22} & 0\\ 0 & 0 & Q_{66}\end{bmatrix}\begin{bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{bmatrix}$$

Because the plate is thin, these three stresses within the plate are assumed to very little from the magnitude of stresses at the top and the bottom surfaces. Thus, they can be assumed to be zero within the plate also.

$$\begin{bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{bmatrix}=\begin{bmatrix}S_{11} & S_{12} & 0\\ S_{12} & S_{22} & 0\\ 0 & 0 & S_{66}\end{bmatrix}\begin{bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{bmatrix}$$

S11 = S22 = (1-ν) (1+ν) / E

S12 = S21 = (-ν) (1+ν) / E

S66 = (1+ν) / E

Below are the tables for the comparison of results in NX and with that of theory from the compliance matrix.

Table 6: Results Comparison for Double Base Propellants

Source	ε_{xy}	εy	ε_{xy}
ANSYS	0.206x 10-3	0.206x 10-3	----------
Theory	0.306x 10-3	0.263x 10-3	0.299x 10-3
Difference	0.32	0.21	

Table 7: Results Comparison for Triple Base Propellants

Source	Ex	εy	εxy
ANSYS	0.354407	0.354407	----------
Theory	0.306992	0.369257	0.3358
Difference	0.13	0.04	

Summary: The images for the designs, deformations, and Vonmises stress are shown along with the tabulated results for the double and triple base propellants. The missile performance is also validated. The motor body is a thin shell such that a small elemental portion is considered as a small lamina and the radial and longitudinal stress not considered as the plane stresses acting on the lamina and the corresponding deformation values for the applied stress are compared with that of theoretical values.

CONCLUSIONS

The structural analysis performed on the anti-tank guided missile MILAN 2T motor body which was designed in NX for varying dimensions and thickness of three motor body designs and analyzed in the NX simulation by applying the loads imposed by two different propellants namely double base and triple base propellants have shown that maraging steel has less deformation (0.109mm for double base and 0.188mm for triple base) when compared with that of Al alloy and brass due to its high structural performance and load bearing capability without disturbing the performance characteristics of the missile. Hence it can be concluded that maraging steel is a better reliable material for the use of missile motor body casing.

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